NASA

TECHNOLOGY APPLICATION TEAM PROGRAM

Applications of Aerospace Technology in the Environmental Sciences

interim report

october 11, 1971 – april 10, 1972

RESEARCH TRIANGLE INSTITUTE

RESEARCH TRIANGLE PARK, NORTH CAROLINA

ABSTRACT

This interim report covers the activities of the National Aeronautics and Space Administration (NASA) Technology Application Team (TATeam) located at the Research Triangle Institute (RTI) during the period October 11, 1971 to April 10, 1972. This program (RTI Project No. 42U-709) is supported by NASA Contract No. NASW-2343. The NASA Technical Monitor assigned to this project is Mr. Charles Eastwood, Technology Applications Division, Technology Utilization Office, NASA Headquarters, Washington, D. C.

The work reported here was performed by J. N. Brown, Director, Center for Technology Applications; Franklin A. Ayer, Project Leader and Manager, Environmental Technology Department; and R. P. Donovan, Senior Engineer, Research Triangle Institute, Research Triangle Park, North Carolina.

The principle objectives of the RTI TATeam program are to identify new applications in the general area of environmental sciences for NASA generated technology and to stimulate the actual implementation of NASA technology in the environmental sciences with significant impact on the nation's effort to protect the environment.

LIST OF ABBREVIATIONS

AP	Air Pollution
ARC	Ames Research Center
CH_4	Methane
TATeam	Technology Application Team
BATeam	Biomedical Application Team
CO_2	Carbon Dioxide
CO	Carbon Monoxide
COSMIC	Computer Software Management and Information Center
EPA	Environmental Protection Agency
FRC	Flight Research Center
GSFC	Goddard Space Flight Center
HCHO	Formaldehyde
Hdqtrs	NASA Headquarters
IAA	International Aerospace Abstracts
ICRPG	Interagency Chemical Rocket Propulsion Group
IR	Infrared
KSC	Kennedy Space Center
LeRC	Lewis Research Center
LRC	Langley Research Center
MOS	Metal Oxide Silicon
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCSTRC	North Carolina Science and Technology Research Center
NDIR	Nondispersive Infrared
NIOSH	National Institute for Occupational Safety and Health
NO_x	Nitrogen Oxides
N_2O	Nitrous Oxide

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LIST OF ABBREVIATIONS (Cont.d)

NSWMA	*National Solid Wastes Management Association*
ONAC	*Office of Noise Abatement and Control*
OSHA	*Occupational Safety and Health Administration*
R&D	*Research and Development*
RDC	*Regional Dissemination Center*
RTI	*Research Triangle Institute*
STAR	*Scientific and Technical Aerospace Reports*
SO_2	*Sulfur Dioxide*
STIF	*Scientific Technical Information Facility*
TUO	*Technology Utilization Office*
TUD	*Technology Utilization Division*

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TABLE OF CONTENTS

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TABLE OF CONTENTS (CONT'D)

1.0 INTRODUCTION

1.1 Introductory Comments

In order to solve problems of major importance, small inter-disciplinary teams at research institutes throughout the United States have been organized by the National Aeronautics and Space Administration's (NASA) Technology Utilization Office (TUO) to develop and apply effective methods for transferring NASA-generated technology to applications in the public sector. These Technology and Biomedical Application Teams (TATeam and BATeam) are actively engaged in effecting such transfers in areas of air pollution control, water pollution control, transportation, mine safety, criminal-istics, law enforcement, postal services, urban construction and biomedicine.

The National Aeronautics and Space Administration (NASA) has been a leader and innovator in the establishment, study, and assessment of technology transfer programs since that agency was established by the Space Act of 1958. Through its Tech Brief, Special Publications, Technology Survey, and Regional Dissemination Center programs, NASA has been successful in transferring the results of aerospace R&D to an impressive number of nonaerospace applications.

More recently NASA has established a program which uses an active and directed methodology. In this program, application teams have been established under contract to the NASA Technology Utilization Office. The application team methodology is active in that specific problems are identified and specified through direct contact with potential users of aerospace technology. The process is directed in that teams interact only with potential users who are involved in reaching selected national goals. Four teams concentrate in the public sector area and have been established at the following institutions:

Research Triangle Institute
Post Office Box 12194
Research Triangle Park
North Carolina 27709

I.I.T. Research Institute
10 West 35th Street
Chicago, Illinois 60616

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

ABT Associates, Incorporated
55 Wheeler Street
Cambridge, Massachusetts 02138

This report covers the accomplishments and activities of the team located at the Research Triangle Institute (RTI) for the period October 11, 1971 to April 10, 1972. In the remainder of Section 1.0, team objectives and methodology are presented.

1.2 Application Team Program

The specific objectives of NASA's application team program in environmental sciences are as follows:

- Transfer NASA-generated technology to applications in the environmental sciences in order to solve environmental problems of major importance;

- Carry the transfer process to the stage of implementation in order that the potential benefits of technology are in fact realized;

- Analyze, refine, and document the manner by which the transfer of aerospace technology to the environmental sciences is accomplished in order to enhance the understanding of active processes of technology transfer; and

- Motivate potential adopters of aerospace technology in environmental organizations involved in generating advanced technology, and individuals who can influence technology transfer programs to become actively involved in more comprehensive technology utilization programs.

A description of the TATeam program can be facilitated by reference to Figure 1. Basically, the team represents an interface and communication channel between scientists and engineers in the Environmental Protection Agency (EPA) and the body of scientific and technical information that has resulted from the nation's aerospace Reserach and Development (R&D) effort.

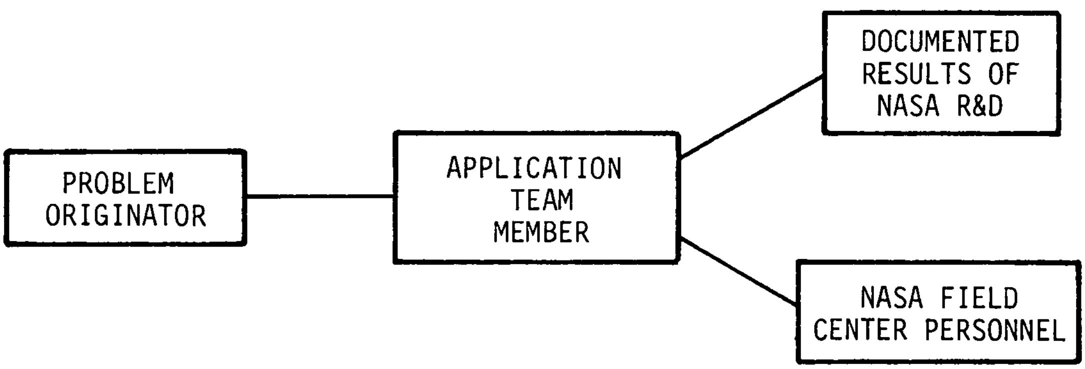

Figure 1. Possible Mechanisms for Transfer of Technology.

The TATeam attempts to couple the technological problems and requirements being encountered in EPA with relevant aerospace technology and, in particular, NASA-generated technology. The team actively engages in identifying these problems through direct contact with EPA centers, staffs, and the problem orginators. The identification and specification of environmental problems is followed by a search for technology which may be relevant to solutions to these problems.

Generally, technology relevant to specific problems is identified through two approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R&D effort, and (2) direct contact with the engineering and scientific staff at NASA field centers. Technology representing potential solutions to problems is channeled through the team to the problem originator for evaluation and implementation as a solution to his problem. Alternatively, and less frequently, the team establishes a contact between the problem originator and NASA field center personnel, and the transfer of information between NASA and EPA becomes more direct.

Assistance to the problem originator in implementing solutions to problems is an important part of the application team program. This assistance may take any one of a number of different forms. Direct assistance to the problem originator in his efforts to implement a solution is frequently involved. During this reporting period, NASA's Technology Utilization Division (TUD) has utilized reengineering or adaptive engineering facilities of various NASA centers in those cases where feasibility had to be demonstrated. The teams are responsible for identifying the NASA technology which is potentially a solution to a specific problem and for specifying the changes required in this technology. This allows the teams to demonstrate that the technology is in fact a solution to the problem and allows the problem originator to make use of the NASA technology in his work which might otherwise be impossible.

The successful transfer of aerospace technology to an individual or group in the public sector followed by successful implementation of the technology with resulting benefits to the accomplishment of some public sector objective is called a "technology application". Also included in the definition of technology application is the constraint that the public sector application and objective involved in the technology application be different from the aerospace application and objective for which the technology was originally developed. This objective should be distinguished from that involved in a program to enhance the diffusion or broad utilization of demonstrated applications of technology. Technology transfer involves crossing what may be thought of as an "application or objective barrier", and it involves complete evaluation of the new application; diffusion involves neither of these requirements.

A specific methodology is applied by the team in its efforts to effect applications of aerospace related technology. This methodology is discussed in the following section.

1.3 Methodology

The general methodology used by the TATeam is divided into five major areas of activity -- (1) problem selection, (2) problem definition, (3) search for relevant aerospace technology, (4) adaptive engineering requirements, and (5) coordination of adaptive engineering projects.

This methodology was used as a framework for the TATeam's operation; it should be stressed that few problems actually proceed from "problem selection" to "coordination of adaptive engineering projects" as described in the paragraphs to follow. The team's action at each phase of the transfer process was determined primarily by what was required to transfer NASA technology so that the impact of technology on environmental sciences was maximized. Figure 2 is a flow chart of the methodology used by the TATeam.

Problem Selection - Problem selection in the context of the TATeam program consists of two elements: (1) The selection of specific problems for further consideration, and (2) The selection of the most appropriate organizational unit within the responsible Federal agency to work with in attempting to solve the problem.

Both elements are important in achieving the transfer of NASA technology to the environmental sciences. The characteristics of environmental problems considered in selecting specific problems for investigation by the TATeam are:

- The problem must be of major importance in the environmental sciences; i.e., solving the problem will have significant economic impact on environmental control programs, will accelerate the progress of environmental control programs, will reduce the economic loss resulting from environmental pollution, or will reduce the health hazard or nuisance value associated with environmental pollution.

- The problem is viewed by the responsible Federal agency as one of major importance at the present and, as a result, solving the problem is given high priority by that agency.

- The technological aspects of the problem are relevant to NASA technology.

The criteria which are important in selecting the appropriate organizational unit and individual to work with in solving a particular problem or category of problems are:

- The organizational unit or individual must assign high priority to solving the problem and must be taking action to solve the problem.

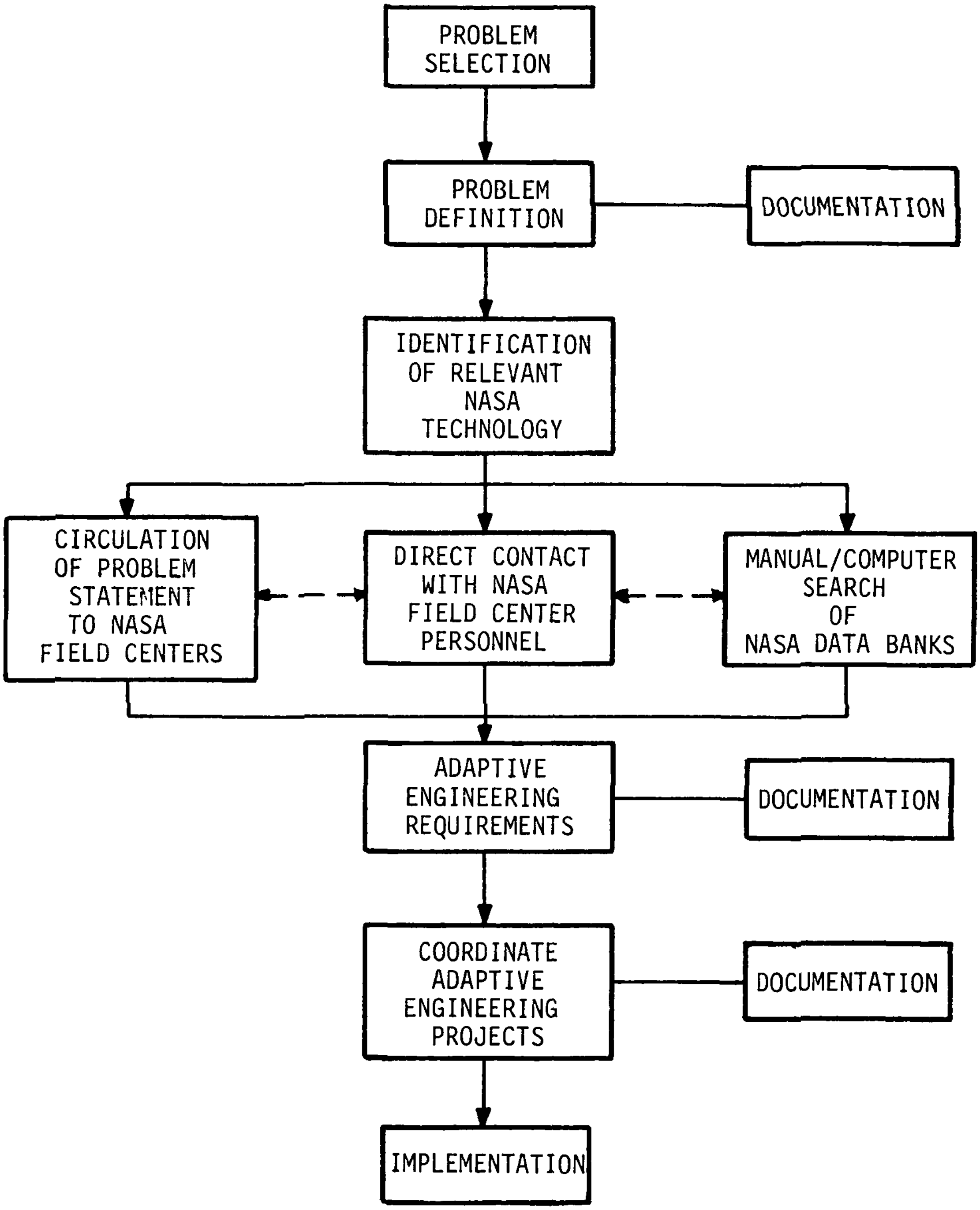

Figure 2. TATeam Methodology Flow Chart.

- The organizational unit or individual must be able to specify the technological requirements of the problem, must be able to evaluate the relative merit of potential solutions to the problem, and must be in a position to utilize the demonstrated solutions.

In actual practice, the selection of problems by the TATeam did not proceed as a two-phase process as implied in the preceding discussion, although all of the criteria delineated in the preceding were applied. Rather, the problem selection process proceeded generally as follows:

- The selection of general problems or problem categories was made on the basis of discussions with appropriate individuals in relatively high positions within EPA and other Federal agencies, and on the basis of recent articles in the open literature and recent government reports. For example, in the area of air pollution control, high priority was placed upon obtaining new or improved gaseous and particulate monitoring systems. Also, from a recent article in Environmental Science and Technology [Ref. 1] it was pointed out that solid state sensors were urgently needed, that certain generally specified improvements were needed in existing monitoring systems for the most common pollutants, and that major improvements were needed in monitoring systems for many of the air pollutants which are now being given high priority within EPA; i.e. lead, asbestos, fine particulates, selenium, chlorine, and many others.

- Following selection of problem categories or general requirements, the team identifies the particular individual or group responsible for solving the problems or satisfying the requirements selected. In many cases this identification is obvious; in other cases two or more groups are involved and the TATeam has to determine which group best satisfies the criteria already discussed.

- The final step in problem selection involves identifying specific technology requirements or problems existing within the more general problem category already selected. It is at this point that judgments concerning relevance of NASA technology to solution of the problem are made. Finally, this step leads directly to the problem definition phase which is discussed below.

Problem Definition - After problems have been selected using the above procedures and criteria, each problem must be carefully defined. In the definition phase, it is important to have face-to-face meetings between the team members and the cognizant EPA or other agency technical personnel.

These meetings determine more completely the context of the specific problem in relation to agency goals. These meetings allow the TATeam to determine the specific environmental problems to be solved and the technological impediments to that solution. TATeam members are experienced engineering and research personnel and can offer considerable assistance in outlining the specific engineering requirements. Problems are documented in the language of the engineering and physical sciences. Specialized terms, where used, are defined in conventional engineering and physical science language.

In general, problem definition has two major purposes: (1) to assist the problem originator in determining the specific technological requirements of the problem under consideration; and (2) to define the technological requirements in language which is easily understood by NASA scientists and engineers. This was quickly accomplished because of the past TATeam experience in the Technology Application Team program and the Biomedical Application Team program.

Identification of Relevant NASA Technology - NASA technology relevant to the solution of environmental science problems is identified by three search processes:

- Manual and computer search of NASA data banks;
- Direct contact with NASA scientists and engineers at NASA field centers; and
- Circulation of problem statements to NASA field centers.

The general procedure in identifying relevant NASA technology is initiated by performing manual or computer relevant technology searches with the objectives of identifying individuals or groups at NASA field centers who could be contacted directly in an attempt to find potential solutions to problems. Following, or in parallel with relevant technology searching, individual scientists and engineers at NASA field centers are contacted in an attempt to identify NASA technology relevant to the solution of specific problems. Problem statements are circulated to field centers through Technology Utilization Officers only when relevant technology searching and all direct contacts with field centers failed to reveal a potential solution. These three mechanisms are described in more detail in the following paragraphs.

Computer relevant technology searches for the RTI TATeam are performed at the North Carolina Science and Technology Research Center (NCSTRC) and at NASA's Scientific and Technical Information Facility (STIF). In general the following procedure was used:

- Conducted a computer search on all problems investigated by the TATeam unless a manual search either identifies a solution or clearly indicates that a computer search would not uncover relevant technology.

- Applied, to the extent feasible, the search strategy findings that Dr. William Clingman, Clingman and Company, Inc., presented in his study of the effectiveness of computer search strategies.

- Designed search strategies to make both direct searches for solutions and indirect searches for technology developed for applications unrelated to specific problems but relevant to the solution of those problems.

The practice of directly contacting individuals within NASA field centers concerning specific problems was emphasized. All available sources of information on appropriate center contacts were used. These sources of information included NASA field center staffs and Technology Utilization Officers, other BAT/TATeam members, government reports, BAT/TATeam Weekly Contact reports, and the Technology Applications Center at George Washington University. An effort was made to insure that the individuals who were contacted were in fact involved in work directly related to the problem and that the TATeam member initiating the contact had available all information which was of value to the center scientists or engineers contacted. Also, other contractual BAT/TATeams, including RTI's BATeam, were contacted in order to keep abreast of the NASA technology being made available to them for possible problem solutions.

Where appropriate, circulation of problem statements to NASA field centers is highly selective. Circulation lists are prepared for all problem statements circulated to NASA field centers, both to assist the field center Technology Utilization Officers and to insure that as many of the individuals who might be able to assist in solving a specific problem did in fact receive that problem statement.

When relevant NASA technology, representing a potential solution to a specific problem, was identified by the TATeam, this technology was documented to the extent required to clearly demonstrate the potential applicability of the technology to the organization which originated the problem. Such documentation was in general a description of the relevant technology, plans for adapting the technology to the specific application involved, estimates of the benefits which could result, and other required data and documentation. The extent of this documentation of relevant technology depended on a number of factors including the capabilities and knowledge of the problem originator(s), the complexity of the relevant technology, the reengineering required, accessibility of existing technology documentation and, most importantly, what documentation is required to quickly and effectively present a potential solution based on NASA technology to the user organization.

Adaptive Engineering Requirements - Once technology is identified by the TATeam, evaluated, and found to be potentially applicable as a solution to a specific problem, the relevant technology would in general be adapted

or changed in some way before it is implemented as a solution to the originator's problem. This might involve minor changes or rather extensive reengineering of a circuit, electronic device, mechanical mechanism, chemical process, or system. In other cases, computer software might require modification, ranging from minor code changes to the creation of entire programs based upon NASA generated computer program documentation. Still other situations might require the adaptation of management systems and operational procedures.

The experience gained by NASA's TATeam program indicates that even when potential solutions utilizing NASA technology have been identified it is difficult to effect implementation of the solutions, thus completing the technology transfer process, because in general mechanisms for performing the required adaptive engineering or reengineering do not exist. Thus, it has become clear that in order to effectively transfer NASA technology to nonaerospace applications the teams must become involved in the adaptive engineering process. This, of course, begins with defining the requirements for adaptive engineering. Consequently the TATeam devoted a significant portion of its efforts toward defining these adaptive engineering requirements. Adaptive engineering requirement specifications are generated for problems selected by RTI and NASA on the basis of the benefits which could result, NASA's contribution to the technology representing the potential solutions, and finally, the specific reasons that the adaptive engineering and implementation was not proceeding spontaneously. These requirement specifications are generated in order to initiate and guide the adaptive engineering process within the user organization, potential manufacturers of the resulting product if applicable, NASA field centers and contractors or other organizations. The content of these required specifications are directed toward the fabrication of prototypes to evaluate and demonstrate the validity of potential solutions which utilize NASA generated technology.

These requirement specifications are generated through an engineering analysis and synthesis study, utilizing information contained in the problem definition and relevant technology documentation. This analysis and synthesis process requires additional contacts both with individuals within the user organization and within the NASA field centers as well as contractor organizations. Included as an integral part of these requirement specifications are a complete evaluation or test protocol. In general, the requirement specifications constituted a proposal and contained objectives, adaptive engineering specifications and plans, test and evaluation protocol, and, where applicable, estimates of cost and schedule.

Coordination of Adaptive Engineering Projects - At the direction of NASA, the TATeam coordinated adaptive engineering projects at NASA field centers and other appropriate organizations. More specifically, the team, in selected cases and where appropriate, identified the capabilities required for specific adaptive engineering projects within NASA field centers and other organizations including NASA contractors and the Research Triangle Institute. Following the authorization and initiation of adaptive

engineering projects, the TATeam, throughout the performance of the project, maintained communication between the adaptive engineering project staff and appropriate individuals within the user organization in order to assure that additional information needed by the project team could be obtained rapidly and that, when decisions between alternate approaches must be made, these decisions would involve both user organization and project staff. Following the completion of the adaptive engineering and prototype fabrication, the TATeam coordinated the evaluation and test procedures to insure that these tests were complete and that they took into consideration all conditions under which the system or device must function. Finally, the TATeam is prepared to demonstrate or to assist NASA or the user organization in demonstrating the effectiveness of the system or device to other user organizations, potential manufacturers and other organizations designated by NASA.

Documentation - Documentation is an integral part of the team methodology; it is involved at most steps in the process, as indicated in Figure 2. Documentation allows analysis of the technology application process and assessment of the program in general. At present, the Teams report on a weekly, monthly, and semiannual schedule. Effective communication is required between teams, potential problem originators, NASA TUO and field centers and other individuals who are in a position to make use of information resulting from technology applications accomplished by the teams.

1.4 Technology Application Team Composition

The RTI team is a multidisciplinary group of engineers and scientists. During the reporting period, the following individuals were involved in this program:

Name	*Background*	*Responsibility*
Dr. James N. Brown, Jr.	Electrical Engineer	Laboratory Supervisor
Mr. Franklin A. Ayer	Civil Engineer	Team Director
Mr. Robert P. Donovan	Mathematics and Physics	Solution Specialist

The experience and special capabilities of other individuals at RTI are frequently used as needed in the TATeam program.

1.5 Definition of Terms

In the technology application team program, a number of terms have evolved which describe the elements and processes in this program. Because of their number and unfamiliarily to many readers, these terms are listed and defined in this section for easy and quick reference.

Problem Originator or Researcher - An individual seeking a solution to a specific technological problem.

Technology Application Team - A multidisciplinary group of engineers and scientists applying aerospace technology to public sector problems and, at the same time, attempting to understand and optimize the methodology for effecting such applications of technology. The methodology used by the TATeam includes (1) problem selection, definition, and specification; (2) identification of potential solutions to problems by manual and computer information searching, circulation of problem statements to NASA field centers, and contacts with NASA engineers and scientists; (3) evaluation of potential solutions, to include adaptive engineering requirements and the coordination of these projects; (4) implementation and adoption by problem originators of aerospace technology as solutions or partial solutions to environmental problems; and (5) documentation.

Problem - A specific and definable technological requirement that cannot be satisfied with commercially available equipment or through the application of information or knowledge available to the problem originator through routinely used information channels.

Potential Technology Application - Aerospace technology identified as having a high probability of solving a public sector problem, which causes the problem originator or using agency to respond in a positive manner, and which has a high probability of being implemented or adopted if the identified technology solves the problem successfully.

Technology Application - The implementation and adoption of aerospace technology which solves or aids in solving a public sector problem. The public sector application involved is one which is different from that application for which the aerospace technology was originally developed.

Problem Statement - A concise, written statement of a problem in sufficient detail to allow a computer search to be performed by information search specialists and to enable NASA engineers and scientists to consider possible solutions to the problem.

Computer Information Search - A computerized information search of the aerospace information bank established by NASA and made available through six Regional Dissemination Centers in the United States. This information bank consists of approximately 700,000 documents which have been indexed and abstracted in the Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA).

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2.0 TECHNOLOGY APPLICATIONS AND POTENTIAL TECHNOLOGY APPLICATIONS

2.1 Technology Applications

During the reporting period, one application of aerospace technology was accomplished and is discussed in the following summary.

RTI/AP-61, *Mathematical Models for Prediction of Pollutant Formation During Combustion*

One objective of air pollution control is to control emissions of nitrogen oxides and combustible particulates (carbon, hydrocarbons, etc.) by modification or control of the combustion of fossil fuels in domestic, commercial, and industrial boilers. Variables which affect formation of these pollutants during combustion are fuel atomization, evaporation, particle size, burner and combustion chamber design, chamber materials, fuel/air ratio, flame temperature and turbulence or mixing.

Because of the large number of variables, and a need to determine the most critical one to pollution formation, a mathematical model that describes the combustion process was required. Such a model should be able to predict the effects of numerous critical variables on the temperature, concentration and velocity profiles within the flame.

Five basic computer programs (coded ODE, ODK, TBL, TDE, and TDK) developed by the Interagency Chemical Rocket Propulsion Group (ICRPG) to predict various aspects of the combustion process were known to the researcher. The assumptions, limitations, and applications of these programs, and their latest modifications, condensations, and utilization were not known. Also, the ability of these models to predict experimental data, the availability of experimental data, and the NASA agencies adept in using these programs to predict the chemistry and aerodynamics within the flame or combustion chamber were unknown.

The TATeam established personal contact between the problem originator and NASA scientists at the Lewis Research Center and the Interagency Chemical Rocket Propulsion Group, obtained the computer programs and initiated a computer search at NASA STIF which uncovered eleven documents that were relevant to the solution of the problem.

These personal contacts, computer programs and documents provided EPA with the necessary insight required to define the problem of modelling turbulent fossil-fuel combustion. Chemical kinetics, droplet/particle combustion, turbulent mixing and flow, and heat transfer were the four areas of NASA technology expertise of primary importance to EPA.

As a result of this technology application EPA researchers have benefited from NASA expertise in complex computer modelling. The ODK program was considered the best approach to chemical kinetics and will form the basis of the model for prediction of pollutant formation during combustion that

is being developed by EPA. The NASA funded work on droplet/particle combustion will probably form the basis of the droplet combustion part of EPA's model. The heat transfer work performed by Lewis Research Center and other researchers will form the basis for making predictions.

2.2 Potential Technology Applications

At the beginning of this study problem RTI/AP-10/26; Development of an Advanced Pollutant Sensor for Methane (AP-10) and for Total Hydrocarbons (AP-26)" was considered as fulfilling the criteria for a potential technology applicant. During this reporting period one other problem, RTI/AP-71, "Instrumental Methods for Analysis of Formaldehyde in Ambient Air and Auto Exhaust" achieved the status of a potential technology applicant and was approved and funded as an adaptive engineering project. These two problems are summarized below.

RTI/AP-10/26, *Development of Advanced Pollutant Sensor for Methane (AP-10 and for Total Hydrocarbons (AP-26)*

Methane (CH_4) is one of the naturally occurring background constituents in the atmosphere. Although methane is relatively nonreactive and does not undergo photochemical reactions, it is important to be able to measure the amount of methane in urban environments, so that the concentration of reactive hydrocarbons in the atmosphere can be determined (i.e, total hydrocarbons minus methane equals reactive hydrocarbons). These reactive hydrocarbons take part in the formation of "photochemical smog", which is the classical terminology for an air pollution system characterized by photochemical reactions between oxides of nitrogen and many organics in the presence of sunlight. Presently a gas chromatographic technique is used for determining CH_4 in ambient air.

Total hydrocarbons are defined as methane plus C_2 to C_6 organics and comprise 95 to 99 percent of the hydrocarbons in the atmosphere. The C_2 to C_6 hydrocarbons react chemically with nitrogen dioxide in the presence of sunlight to produce "photochemical smog" (i.e. ozone, peroxy-acetyl nitrate) which can cause eye irritation, plant damage, visibility reduction, and deterioration of materials. A knowledge of the concentration of total hydrocarbons in the atmosphere is useful in determining pollution due to automobiles and incineration, evaluating smog control devices, and prediction of smog episodes. At the present time, instrumentation using a flame ionization detector and gas chromotographic techniques have been used to determine total hydrocarbons in ambient air.

Various solutions have been proposed to these problems including a laser detection scheme for total hydrocarbons. A particularly simple and inexpensive technique is that of the thin film detector being developed further at Marshall Space Flight Center (MSFC). This thin film is indium sesquioxide; it was developed by the General Electric Company under a NASA contract and is manufactured and marketed as a hydrogen detector. Previous

RTI work has shown that the thin film is responsive to methane and total hydrocarbons. An evaluation of this potential is being carried out at MSFC. This is a high priority problem and through the efforts of the TATeam, the Technology Utilization Division, NASA Headquarters has funded MSFC to develop, fabricate and test a thin film hydrocarbon detector. If the reengineering is successful, it will provide EPA with a solid state sensor for methane and total hydrocarbons.

RTI/AP-71, *Instrumental Methods for Analysis of Formaldehyde in Ambient Air and Auto Exhaust*

Formaldehyde (HCHO) has been shown to be an eye irritant and contributes to photochemical reactions in the atmosphere. Its role in smog formation and its fate in the atmosphere are, however, not completely understood at this time. The major source of atmospheric HCHO is the automobile. Control techniques proposed to reduce hydrocarbon emissions in automobile exhausts may cause a significant increase in HCHO emissions. Thus, the role of HCHO as an air pollutant would be accentuated.

At the present time manual or automated, wet-chemical techniques are used to monitor HCHO in the ambient air and automobile exhausts. These methods are cumbersome, time consuming, and subject to interferences.

The joint NASA/EPA funding of Dr. Laurence W. Hrubesh, Lawrence Livermore Laboratory, Livermore, California, that is being negotiated is in direct response to this problem. By using solid state devices Dr. Hrubesh plans to redesign a microwave spectrometer so as to make an ecomomical, practical instrument for measuring formaldehyde. Microwave spectroscopy has been championed by Mr. William White, Langley Research Center (LRC) for six or seven years and it now appears that this technique is an excellent one to solve the problem.

2.3 Generic Technical Areas of NASA Expertise

During this reporting period the TATeam investigated various generic technical areas of NASA expertise from which solutions to air pollution problems might logically be expected to emerge. The six specific subjects discussed in this section represent the most promising areas for intensive searching for NASA technology that have a high potential for solving air pollution problems.

The generic areas identified vary from the highly specific to those that are very broad and general. Several respond to an EPA requirement more than they describe a first-order NASA technological strength.

2.3.1 Nondispersive Infrared (NDIR) Instrumentation

Two activities within NASA make this area highly exciting and capable of near-term technological payoffs with major impacts on providing solutions to important air pollution problems facing EPA. These activities are: (1) the support of fluorescent source NDIR instrument development at Arkon Scientific Laboratories, Berkeley, California; and (2) the heterodyning patents of Dr. John Dimeff, Ames Research Center (ARC).

Fluorescent Source NDIR - Under funding provided by both ARC and the Manned Space Center, (MSC), Arkon Scientific Laboratories has developed an instrument for measuring carbon monoxide (CO) at ambient pressure [Ref. 2]. This instrument is scheduled to be flown on the Skylab and modifications of it are being reengineered as a measuring device for applications in air pollution and other areas. A commercial instrument is planned for production in 1972. Four prototypes of this commercial version are scheduled to be delivered to NASA for testing purposes.

NASA's requirements and funds brought this instrument into being. The principles by which the fluorescent source detector operates are well known and can be found in the open literature. The patents which describe the instrument design are the property of Arkon Scientific Laboratories. NASA funds provided the incentive to incorporate these principles and design features into a working instrument. Consequently, the commercial version to be introduced by Arkon Scientific Laboratories is, in effect, a duplicate or an outgrowth of the CO instruments previously built for NASA. The CO detector to be used on Skylab is the production prototype for the commercial version of the instrument.

The same instrument design principles, and in certain cases the details, are also applicable to instruments for measuring other gases such as CO_2, SO_2, NO_x, and N_2O. Arkon plans to market commercial instruments for detecting these gases later in the year or early in 1973. Some of the modifications or changes necessary to adapt the instrument to detection of other gases have been funded by EPA.

Heterodyning Concepts - The heterodyning of various infrared (IR) signals is an alternative method of achieving high signal-to-noise ratios in NDIR instrumentation [Ref. 3]. The basic patents for these ideas belong to NASA under the name of John Dimeff, ARC. These patents are related to the work done by Arkon Scientific Laboratories as described above in that in at least one version a calibrated sample serves as a fluorescent source when excited to fluorescence by a mechanical pump; that is, the gas is excited to fluorescence by pressure. This is the emission-absorption combination of heterodyning. Other ideas such as the absorption-absorption scheme have also been described in the open literature. The feature that these approaches share is that the output signal depends on heterodyning two signals, one of which comes from a calibrated sample of a specific species, and the second of which depends upon the concentration of that species in an unknown gas sample. Without a contribution from each cell the output signal, measured at the sum or difference frequency, is zero. The magnitude of the signal at the mixed frequency is proportional to the concentration of the species in the unknown cell (among other things).

These concepts take on particular significance because of the interest of Royco Instruments in producing an instrument based on these ideas. NASA has issued a license to Royco Instruments to produce instruments based on the Dimeff patents and Royco is currently contemplating production of such an instrument. Royco feels that the versatility of their instrument (it can be used to measure a large number of pollutants by simply changing calibrated cells) plus its high sensitivity guarantees its broad application and popularity.

Two high priority problems being pursued by the TATeam which could be solved by the successful development of NDIR instrumentation are discussed below.

RTI/AP-27, *Development of Advanced Pollution Sensor for CO*

This problem was developed by the TATeam in conjunction with EPA's Division of Chemistry and Physics. This is a high priority problem in EPA and the probability of solving it is high. The work being done at Arkon Scientific Laboratories was known by EPA but the possible development of the Royco instrument was brought to EPA's attention by the TATeam. Close coordination with ARC made this possible.

RTI/AP-41, *Development of Advanced Pollutant Sensor for Oxides of Nitrogen*

This problem was developed in conjunction with EPA because a nonwet chemical technique is needed for measuring specifically NO, NO_2 or NO_x in ambient air, auto exhausts, and stack effluents. The fluorescence NDIR source detector, which is being funded by EPA at the present time, may be used to solve this problem.

2.3.2 Mass Spectroscopy

NASA's interest in mass spectrometers covers the entire spectrum, both large and small, but its unique capability exists in the generic area of miniaturized mass spectroscopy. For a number of years NASA has been building flight models of mass spectrometers to carry out real time analysis of gases in the air or in space. A recent impressive achievement of NASA's program is the development of a quadrupole mass spectrometer to mount under an astronaut's chin inside his helmet which is capable of monitoring the major constituents of his exhaled breath. The same developmental team (at Analog Technology, Inc.) now proposes to extend this concept to monitoring trace gases in the exhaled breath. In order to measure trace gases a tandem quadrupole mass spectrometer arrangement appears necessary but it can probably be built with similar impressive miniaturization.

A second useful mass spectrometer now existing in the NASA inventory of instruments is a 28 lb. magnetic spectrometer capable of 6-12 simultaneous channel readouts. This magnetic instrument does not scan like a conventional mass spectrometer but simultaneously measures the major life support components in a given atmosphere. It was used recently in an underwater environment (TEKTITE II) to analyze the waste products of plankton on the ocean floor [Ref. 4]

A third mass spectrometer capability also exists within NASA as a five pound quadrupole unit was built at Langley Research Center (LRC) primarily to evaluate a cold cathode source for measuring life support gases in a given atmosphere. Additional mass spectrometer capabilities existing in NASA are: (1) a design program, now in computer language designs magnetic mass spectrometers with given performance goals; and, (2) methods for reducing the readout from a complex sample employing appropriate mathematics and computer coupling has been developed. An interfacing capability is probably needed before widespread use of a mass spectrometer in air pollution is realized.

The RTI TATeam hopes to promote the application of miniaturized mass spectrometry to various air pollution problems. A TATeam problem entitled, RTI/AP-48, "Modifications to Mass Spectrometry to Enhance Its Performance in Air Pollution Monitoring," will continue to be a high priority problem even though scientists and engineers in EPA have become generally disenchanted with mass spectrometry and are concentrating on other techniques. A mass spectroscopist working with the Cleveland Air Pollution Division (Dr. O.M. Uy) remains optimistic about the potential possibilities of the mass spectrometer as a multi-component analytical tool for air pollution. With his application in mind the TATeam is developing an instrument specification which will describe typical performance properties for air pollution when the specification is completed it will be circulated among NASA field centers.

2.3.3 Solid State Sensors

Solid state sensors are classified as a generic area because of the interest expressed in them by air pollution scientists and engineers at all levels. The advantages of solid state devices include the desirable characteristics of high reliability, low cost and ease of use and maintenance. In general, solid state sensors with these features have not materialized to any significant degree as air pollution sensors. EPA is actively seeking the development of solid state sensors and NASA has done considerable research directly related to this high interest area.

Several samples will be cited to illustrate NASA's technological capability. First among the proposed solutions for a methane detector as well as a total hydrocarbon detector, was the suggestion from MSFC that a thin film indium sesquoxide detector be used. This concept is an outgrowth of previous MSFC work which used tungsten oxide as a hydrogen detector. Tungsten oxide films respond only to hydrogen while similarly prepared indium oxide film responds not only to hydrogen but to hydrocarbons. Consequently, this film detector has the potential of being a total hydrocarbon detector or in certain applications (such as in mines where the total hydrocarbon is methane) a methane detector. Funds for adaptive engineering of the thin film sensor has been approved. This work is directly related to TATeam problems discussed in Section 2.2.

A second possible sensor is one that is based on NASA supported work at McDonald-Douglas Aircraft Corporation in the development of various coatings for field effect transistors. In this device a standard Metal Oxide Silicon (MOS) field effect transistor serves as a substrate for an organic coating which possesses the desired interaction properties with the gases to be detected. The coating must respond to the gases or combinations of gases in such a manner as to produce a charge polarization within the coating which then can be detected by the adjacent field effect transistor. It has been proposed by Massachusetts Institute of Technology and the TATeam at ABT Associates [Ref. 5] that a reengineering program be initiated to convert the field effect transistor to a home fire detection device. The RTI TATeam is following this work closely as the transistor, if successfully reengineered may be a useful device for measuring air pollutants.

A third effort by NASA constitutes a large developmental program for various specialized meteorological sensors such as pressure, temperature and moisture in support of measurements of high altitude and space environments. Included in this class of sensor development are many solid state devices such as MOS capacitor meteoroid detectors, piezo junction pressure transducers, fine wire thermocouples and other thin film sensors. Some of these devices are still in current development while others have been developed. With some imagination and reengineering, certain of these sensors may be useful in air pollution. For example, the MOS micrometeoroid detector has an extremely high signal-to-noise ratio for counting the number of high energy micrometeoroids that impact on it. With some reengineering an array of such detectors could serve as a panel for reading out the number-density of high altitude particulates.

2.3.4 Remote Sensing

Remote sensing requires expensive hardware and costly development. In addition to observation platforms on satellites NASA uses both aircraft borne sensors and ground based instruments for remote measurements. Remote sensing, like booster development and production, or spacecraft design and construction, is one of the obvious strengths of the NASA program.

The question arises as to how remote sensing can be used to solve important air pollution problems. A NASA prepared document entitled, "Remote Measurement of Pollution," NASA SP-285, addresses this question in detail [Ref. 6]. The report concluded that remote detection of gaseous pollutants is practical, at least for certain constituents, and that remote particle monitoring, both from airborne and ground based platforms, is also possible although present methods for making remote particle measurements are less effective than those for measuring gaseous constituents. The equipment for implementing remote sensing is generally costly and it does not constitute an important part of the EPA budget. Understandably, the major interest of EPA lies in the tried and proven methods consisting of direct sampling and in-place measurements. Nevertheless, remote sensing interests EPA and this area is one in which NASA has made a major contribution.

Among the remote sensing techniques in which NASA has expertise are IR absorption methods, various laser techniques and the broad area of aerial photography. NASA has active programs in each of these three areas and is committed to the design and construction of relatively expensive equipment. Examples of such hardware include: (1) Fourier interferometer spectrometer at the Jet Propulsion Laboratory (JPL) [Ref. 7]. (2) Lidar system development at LRC [Ref. 8], multispectral photography carried out at several field centers and the tunable laser development at JPL [Ref. 9]. The Fourier interferometer spectrometer is designed for space platform service from which it will monitor, on a global basis, the presence of the common pollutants in the underlying atmosphere. The instrument operates as an integrating detector, summing the net burden over a vertical path. This instrument is now monitoring highway pollutants in the Los Angeles area, sighting along a horizontal path above the freeway to a reflector and the reflection of the signal back to the spectrometer.

NASA lidar work centers chiefly around the activities at Langley Research Center. Just recently LRC completed construction of what is probably the world's most powerful and versatile, moveable lidar system. Previous activities of similar, but lower powered, lidar systems include the analysis of aerosols in the Willamette Valley in Oregon and the analysis of pollutants emitted by power plant stacks in Asheville, North Carolina. This latter activity employs Raman scattering, the results of which are correlated with conventional stack measurements carried out by EPA.

Multispectral photography from airborne platforms is carried out at a number of locations. Typical of these is the facility at Marshall Space Flight Center which routinely maps areas in the vicinity of Huntsville

with multispectral cameras and, with appropriate processing, constructs land use maps for various purposes such as landfill site selection, vegetation condition, strip mine tailings, etc. The amount of data available for analysis will be greatly increased with the launching of the various Earth Resources Technology Satellites (ERTS).

The tunable laser greatly enhances infrared spectrometry now under development at JPL. The use of a laser light source in infrared spectrometry aids efficiency and selectivity because of the relatively high power and extremely narrow monochromatic emission characteristic of the laser source. In the past lasers have operated at one frequency only. The recent availability of tunable lasers, capable of changing their output frequency over at least a limited portion of the spectrum, makes such light sources more practical for pollution detection. One mode of operation is to use the tunable laser as a local oscillator to beat against the incoming IR, generated either by a pollutant's natural temperature or because of some external stimulation such as a lidar pulse. By heterodyning these two signals together one generates a sum or a difference frequency proportional to each. As in the Dimeff concept discussed in Section 2.3.1, this process greatly enhances signal-to-noise ratio and with a narrow, local oscillator signal now available from a tunable laser the sensitivity of detection increases greatly.

2.3.5 Particulate Monitoring

Measurement and classification of particulates in various sources and in the ambient air has become a major EPA problem. NASA has been intimately involved with similar problems throughout its program and, while no obvious solutions are in hand to be applied, the possibility of significant contributions by NASA to the solution of the problem is very real. The lidar technique is one example where particulates have been detected remotely. A remote technique not discussed previously is that of the Doppler shift used at MSFC to measure wind tunnel velocities and, more recently, the velocity of particles in the open atmosphere. This instrument, called the velocimeter, uses a laser to illuminate various airborne particles. If a particle is moving with respect to the laser, a Doppler shift appears in the return signal which is proportional to the relative velocity. This information yields a one dimensional velocity component. Instruments have been constructed consisting of two and three lasers to measure all three components of particle velocity. This same technique can be used to yield size distribution information and appears particularly important as a means for particulate monitoring.

Other particle measurement instruments have been made within NASA. Sandia Laboratories prepared a contamination control handbook under NASA contract in the development of cleanroom facilities for assembling precision instruments for space flight. The Whitfield laminar flowbox is a direct outgrowth of that work.

Chemical composition of particulates has received little attention within EPA and is likely to remain a relatively low priority item, except in research, in that standards for particulate emissions are expressed

at present only in mass per unit volume. At Lewis Research Center a program exists whereby particulates gathered on the filters of a conventional high volume sampler are analyzed for content by both neutron activation and emission spectroscopy. The nuclear reactor at Plumbrook, Ohio, performs approximately 50 analyses per week for this program.

The measurement of high altitude particles has been extensive throughout NASA's history. Thus cosmic dust particles have been analyzed at ARC; measurements of extra terrestrial micrometeoroids in space and monitoring of trophospheric and stratospheric particulates by lidar have been made at LRC. NASA has particle experience across the entire spectrum-from in-place filter analysis to remote detection; from ground level cleanroom problems to those of the upper atmosphere and space. For this reason particulate monitoring is an area of NASA expertise from which the probability of technology applications to contemporary air pollution particulate monitoring problems appears high. EPA's interest in particulate measurements are reflected in RTI's Problem Statement RTI/AP-38, "Measuring Techniques for Airborne Particles"; RTI/AP-47, "Feeder System for Particulates in Gases"; RTI/AP-53, "Developing of Continuous Particle Counting Instrument"; RTI/AP-57, "Analytical Techniques for Trace Metals in Combustion Effluents from Coal and Residual Fuel Oil Sources"; and RTI/AP-67, "Fine Particle Collectors."

2.3.6 Quality Control

One of the major challenges of the Apollo program was the need to assemble a complex system which would be as free from failure as humanly possible. The safety record of the Apollo program demonstrates that the challenge was met. The skills and organizational talents required to perform this unprecedented reliability no doubt have carry over potential to many activities within EPA. In general, such methods are expensive and many EPA programs do not justify the investment. Often it is much cheaper to replace a piece of equipment or a device rather than spend excessive amounts of money to build a device that is inherently reliable. The thinking and philosophy of what constitutes an optimum balance between costs and reliability applies also to the manufacture of instruments for air pollution monitoring and the training of personnel to operate these instruments. Since EPA has little experience in quality control, the transfer of quality control methodology from NASA to EPA would appear to be a valuable input to EPA. How this transfer of technology can be accomplished is by no means clear at present. Problem statement, RTI/AP-65, "Functional Effects of Chemical Agents and the Application of Reference Procedures in Relation to Interlaboratory Comparison of Results," relates to quality control.

2.3.7 Conclusions

These six generic areas constitute a selective discussion of expertise within NASA that have direct relationship to known EPA needs in monitoring air pollutants. Of the six, NDIR instrumentation appears closest to having a major impact on the solution of important air pollution

monitoring problems, mass spectroscopy, on the other hand, appears to be weak because of declining EPA interest. This declining interest stems from two sources: (1) the lack of performance by mass spectrometers in the past; and (2) the present advances made by other techniques in solving EPA problems. Nevertheless, the mass spectrometer appears destined to solve various problems of society and should be pursued.

The remaining generic areas of expertise identified respond to present EPA needs. Solid state sensors and remote sensing are not likely to have near term impact. Their impact, when and if it arrives is likely to be major. Particulate monitoring and quality control are responses to very pressing contemporary EPA problems and while no clear, exciting transfer situations are yet obvious, further exploration of both the problem needs and the NASA experience seem likely to produce mutually beneficial matchups. All generic areas, except remote sensing, are represented by current RTI TATeam problems.

Many other general areas of NASA technology expertise can be identified. One in particular is power generation. A long recognized need exists for improved methods of generating power. Man-made pollution comes primarily from automobiles, power plants and industry in general. Technology for producing cleaner automotive vehicles (such as better batteries and more efficient drive chains for an electric car) and methods for producing cleaner electric power for industry and home use (such as practical solar cells and even more efficient turbine power) are clearly applicable. Power generation experience is a broad field of NASA expertise and has great potential for air pollution impact.

Materials for special applications that have been part of the NASA space program from the beginning also have the potential of solving many public sector problems. Of particular interest in air pollution would be the development of special high temperature materials capable of operating gas turbines at higher temperatures and hence with more efficiency. A subdivision of the materials problem is that of special coatings to exhibit particular properties. Ion plating and sputtering as a means of improved coatings for engine bearings are one example of a potential technology transfer.

These last three generic areas -- materials, coatings and power generation -- are broad areas with less clearly defined specific problems. Opportunities within them will continue to be explored. Again, this grouping is by no means exhaustive. The application of NASA technology to air pollution can come from most any program or area. The areas explicitly identified in this section are regarded as those which should receive first priority in seeking air pollution problems for potential NASA technology applications.

2.4 Related Activities

2.4.1 General

With a TATeam goal of transferring NASA technology in order to solve or even partially solve major problems in the area of environmental sciences, the TATeam can logically work with agencies or organizations other than just the EPA centers responsible for air pollution control. Some of these agencies or organizations include responsibilities for air pollution, noise abatement and control, solid waste disposal, and industrial environmental monitoring and control. The contacts made with these agencies or organizations, personal and in writing, will be discussed briefly in the subsections to follow.

2.4.2 Office of Noise Abatement and Control (ONAC)

Personal contact with the director, Office of Noise Abatement and Control, EPA, was established and the objectives of the NASA-supported TATeam were explained. A follow-up plan for investigating a number of technological requirements or technology-related problems existing in noise abatement and control (to be identified through discussions between members of the TATeam and the director's staff) was submitted. The director accepted the plan and action is underway to develop problem statements.

2.4.3 National Institute for Occupational Safety and Health (NIOSH)

Personal contact was also made with the Associate Director of NIOSH as was made with the Director, ONAC. A plan of action for the mutual efforts of the TATeam and staff members of NIOSH was submitted for review. As of this reporting period the acceptability of this plan has not reached the same stage of operation as the plan submitted to ONAC.

2.4.4 Occupational Safety and Health Administration (OSHA)

Personal contact with the Office of Compliance and Standards, OSHA, was made during this reporting period. The TATeam and BATeam programs were discussed in detail and it was generally agreed that aerospace technology applications could have a significant impact on problems faced by OSHA. Three specific problems were discussed and outlined as follows:

Asbestos Monitoring - Asbestos is physiologically highly active. The effects of exposure to asbestos include asbestosis and three different kinds of cancer.

The present method of measuring the concentration of asbestos fibers in air is to collect dust on a filter and to count the asbestos fibers

using optical or electron microscopy. The asbestos fibers are identified on the basis of aspect ratio; if the length to width ratio exceeds three, it is assumed to be asbestos.

The requirement for a quick field method of determining asbestos fiber concentrations is significant and urgent. The resulting instrument must distinguish asbestos from other dust particles; it must "see" fibers from five microns in length down to probably 0.01 microns; and must have a response time of 3 to 5 minutes. It is likely that ongoing research will demonstrate that the total mass of asbestos is more significant in the dose-effect relationship than is the number of fibers. Therefore a method which would respond to mass as opposed to fiber count would be desirable.

Punch Press Safety - It is known that the injury rate for punch-press operators is excessive; statistics on the actual numbers of fingers and hands severely injured or lost are not available. No fail-safe accident prevention system exists for punch presses. Efforts have been directed toward developing such systems in the past based upon electrical capacitance changes, optical systems, and radiative systems. These developments have been generally ineffective. The most effective (developed by the Atomic Energy Commission) involved attaching sources of radiation to the punch press operator's wrist and incorporating a sensor at various points on the punch press. The proximity of the operator's hands to the punch press prevented or inhibited punch press operation. This system was not used because of the perceived radiation hazard.

System for Estimating Air Contaminants in Industrial Environments - The concentrations of more than 100 specific contaminants in the air of industrial environments are at present estimated using small "reaction tubes" costing approximately 60¢ and having an accuracy of $\pm$ 25 percent. These reaction tubes are 4 inch long glass tubes, approximately 40 mm in diameter, sealed at each end and filled with granulated silica which has been treated with a stain specific to a particular contaminant. In operation the ends of the tube are broken and a controlled volume of contaminated air is pulled through the reaction tube using a hand-held pump which has incorporated in it a critical orifice to control air flow rate. The amount of contaminant in the air determines the amount of staining of the granulated silica. It is assumed that the chemical reaction involved occurs very rapidly with respect to sampling time and that staining, therefore, begins at the input end of the tube and moves down the tube at a rate proprotional to the concentration of the contaminant. Thus, the length of the stained portion of the granulated silicon is an indication of contaminant concentration. At present each batch of reaction tubes for a specific contaminant must be calibrated and a scale prepared for converting length to concentration. Even with calibration $\pm$ 25 percent accuracy is the best that can be achieved.

What is required to improve this situation is either a different concept, a different geometry, or different operational procedures for increasing the accuracy of this rapid on-site contaminant estimation system.

2.4.5 Bureau of Air Quality Control, State of Maryland

TATeam members visited R. Beman, Chief, Division of Air Monitoring, to learn about the "Airmon" system used by the State of Maryland to monitor selected air pollutants. The Airmon system consists of eight remote monitoring sites located in the State of Maryland, chiefly the Baltimore and suburban Washington areas. Each station is patterned after a typical CAMP station and measures SO_2, CO, total hydrocarbons, NO_x, photochemical oxidants and particulates. Of the eight stations, six are fully equipped for these measurements while two are partially equipped. The sites consist of secure, windowless enclosures, measuring 8' x 16' x 10'. They are mounted on a concrete slab but are movable in the sense that they can be picked up and transported to different locations. Power and telephone lines in addition to all the glass manifolds for gases and a stainless steel probe for particulates are installed in the site enclosures. All data are recorded on a strip chart simultaneously while being transmitted over dedicated telephone lines to a central processor back in Baltimore. This system has not yet been accepted but is in the final stages of completion by the contractor (Litton), who is now training state personnel to maintain and operate these units. Four people are the goal for maintenance requirements.

An important feature of this system is its dynamic calibration which is carried out once a day. Each instrument is rezeroed and checked for span once every twenty-four hours. The calibration gases are either purchased from commercial sources as certified gases or obtained from permeation tubes calibrated by the Bureau of Standards (SO_2 and NO_2) or, in the case of O_3, generated on-site. Following calibration there is a zero flush and a settling time before the instrument is put back on operation. This entire calibration cycle is arranged so as not to interrupt the hourly average data at any time; that is, the calibration cycle is begun in the latter portion of one hour and extends through into the beginning portion of the next hour. The total number of points taken within each hour still constitutes a valid sample for each hour.

The system can be expanded to handle thirty stations; the two-wire voice grade telephone line can easily be converted to four.

Among the problems cited by Beman were the following:

- Standardization methods and location of sampling sites.

- Development of the defensible concentration levels for various pollutants.

- Cost of the monitoring station, including initial cost, as well as the operation and maintenance costs, all of which implies the need for more rugged, less bulky sensors and instruments.

Other problems cited included the general need for improved sensor research and specifically the need for better data handling capability. In addition, methods for site selection, now largely arbitrary, should be developed to derive maximum information from the investment.

2.4.6 Division of Air Pollution Control, Cleveland, Ohio

By telephonic means the NASA-supported TATeam program was explained to two members of the Division of Air Pollution Control. Immediate interest was expressed in the area of mass spectrometry. Two problem statements were submitted to the TATeam for consideration -- one of which is considered significant as it requested the use of a mass spectrometer for measuring ambient air pollutants in and around the city of Cleveland. Recent follow-up action resulted in the development of a plan of action which was mutually agreeable to both organizations. This plan is as follows:

- Mail specifications to the Division of Air Pollution Control, Cleveland, Ohio for critique.

- Cleveland-approved specifications to be submitted to various NASA Centers (or contractors).

- Specification responses in the form of proposals to be reviewed by the Division of Air Pollution Control.

- NASA Headquarters, TUD, to make decision to fund program totally or in part.

The sampling system throughout the city of Cleveland consists of both manual and automatic sites which monitor O_2, SO_2 and particulates. Two mobile stations with instruments for sampling SO_2 and particulates are also operational. This activity has been coordinated with Lewis Research Center and much of the data generated by these sampling sites have been analyzed by statisticians at Lewis Research Center to provide descriptive concentration levels over the periods between 1967 and 1970. This information has been compiled in a Lewis Research Center Report [Ref. 10].

2.4.7 National Solid Wastes Management Association (NSWMA)

On 14 December members of the TATeam met with the Executive Director and Technical Director of NSWMA. The purpose of the meeting was to determine if the TATeam could perform the function of transferring NASA

technology to solve solid waste problems. Eleven major problems facing solid waste managers were discussed. Although solid waste management is primarily a materials handling problem, it appears that NASA technology can, in fact, be applied to solve these problems.

During the period of this report six problem statements were developed and forwarded to NSWMA for review. Comments have been received and these comments are being incorporated prior to forwarding to TUD for approval and dissemination to the NASA Centers.

2.4.8 National Environmental Research Center, Cincinnati, Ohio

On 15 December, TATeam members met with personnel assigned to the National Environmental Research Center (NERC), Cincinnati, Ohio. Additional solid waste problems were discussed. This discussion further confirmed the idea that NASA technology was probably applicable to the solution of some of these problems.

2.5 Case Studies

Two marine science application case studies, RTI/OC-10, "Miniaturized Mass Spectrometer Provides Important New Data in Marine Biology," and RTI/OC-16, "A New Technique for Measuring the Osmo-Regulation of Blue Crabs," were completed and published as NASA Technology Applications Bulletin. These studies are covered in Appendix A and B, respectively.

3.0 PROGRAM ANALYSIS

3.1 Environmental Impact Areas

Air pollution is mostly a phenomenon of urban living and occurs when pollutants overburden the capacity of the air to dilute them. Industrial growth, population increases and their dependence on vehicles as a mode of transportation adds greatly to the complexities of the traditional air pollutants.

Fifteen (15) major objectives [Ref. 11] have been assigned to EPA. In view of these EPA problems, the solutions to which are of major importance to the nation and the world as a whole, the TATeam decided to assess the impact of existing problem statements upon EPA's mission. The analysis indicates that if the TATeam problems are solved satisfactorily, then a decisive impact on EPA objectives results. Table 1, Impact of TATeam Air Pollution Problems on EPA Objectives, presents the conclusions of the analysis in matrix form.

3.2 NASA/TATeam Interactions

After determining that the TATeam problems were oriented toward solving major air pollution problems, it becomes necessary to identify specific technology requirements and identify those relevant to NASA technology. Direct contact with NASA scientists and engineers at NASA field centers was emphasized and manual and computer searches of NASA's data banks and the circulation of problem statements were made. Also, an effort was made to insure that the scientists and engineers contacted were in fact involved in work directly related to the problem. In addition, the TATeam member initiating the contact attempted to have available all information that would be of value to the center scientist or engineer contacted.

During the period of this report many contacts were made with NASA centers to keep abreast of NASA technology and to determine how that technology could best be applied to solve air pollution problems. In some cases an individual scientist or engineer was able to give valuable information concerning a technical problem even though the NASA Center to which he was assigned might not be known as the leading center with that specific technical capability. Table 2, TATeam/NASA Center Interactions, covers in abbreviated form contacts made by technical area.

3.3 Adaptive Engineering Requirements

Once technology was identified and evaluated by the TATeam and found to be potentially applicable as a solution to a major problem, the relevant technology generally must be adapted or changed in some way before it can be implemented as a solution to the originator's problem.

Table I. IMPACT OF TATeam AIR POLLUTION PROBLEM STATEMENTS ON EPA OBJECTIVES

EPA PRIORITY AIR POLLUTION OBJECTIVES (REF II)	ACTIVE TATeam PROBLEMS																		
	* AP-10 Development of Advanced Pollutant Sensor for Methane	* AP-26 Development of Advanced Pollutant Sensor for Total HC	* AP-27 Development of Advanced Pollutant Sensor for CO	x AP-38 Measuring Techniques for Airborne Particles	+ AP-41 Development of Advanced Pollutant Sensor for Oxides of Nitrogen	x AP-47 Feeder System for Particulates in Gases	+ AP-48 Modifications to Mass Spectrometry to Enhance Its Performance in Air Pollution Monitoring	x AP-53 Developing of Continuous Particle Counting Instrument	x AP-57 Analytical Techniques for Trace Metals in Combustion Effluents from Coal and Residual Fuel Oil Sources	+ AP-58 Direct Measurement of Flame Temperature in Combustion Processes	x AP-59 High Temperature Sampling Techniques for Kinetic Studies in Combustion Processes	* AP-61 Mathematical Model for Prediction of Pollutant Formation During Combustion	+ AP-65 Functional Effects of Chemical Agents and the Application of Reference Procedures in Relation to Interlaboratory Comparison of Results	+ AP-66 Differential Pressure Transducers for Isokinetic Stack Gas Sampling	x AP-67 Fine Particle Collectors	+ AP-68 Development of a Model Toxicity Testing System	* AP-71 Instrumental Methods for Analysis of Formaldehyde in Ambient Air and Auto Exhaust	≠ AP-72 Storage of Carbon Monoxide at Low Levels	≠ AP-75 X-Ray Fluorescence Spectroscopy
1 Set National Air Quality Standards CO Particulates, SO_x, HC NO_x	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
2 Set National Emission Standards for Hazardous Pollutants				X		X	X		X		X	X	X	X	X	X	X		X
3 Improve State & Local Control Agencies	X	X	X	X	X			X		X	X			X	X		X	X	
4 Accelerate R&D on SO_x and NO_x Control					X		X		X	X	X	X		X		X	X		X
5 Develop more efficient energy processes						X			X	X	X	X	X	X	X		X		X
6 Accelerate industry support for research and stimulate corrective actions												X	X			X		X	
7 Regulate fuel and fuel additivies decrease lead in gas and test emission systems		X	X	X	X			X				X			X		X		X
8 Control motor vehicle emissions under actual road conditions		X	X	X	X		X	X	X	X	X	X		X	X		X	X	
9 Develop and test an effective emission control system for installation in used cars		X	X	X	X			X	X					X	X		X	X	
10 Develop unconventional vehicle propulsion system																	X		
11 Increase research on development of a more efficient transportation system for people and goals																			
12 Conduct more research on the effects of air pollutants on man													X			X		X	
13 Improve Federal State and local monitoring programs	X	X	X	X	X		X	X	X				X	X	X		X	X	
14 Minimize air pollution through land use planning	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		
15 Cooperate with other nations in limiting total amounts of air pollutants emitted																			

* High Priority Problem - NASA Technology Identified High Probability of Technology Transfer

\+ High Priority Problem - NASA Technology Identified, Reasonable Probability of Technology Transfer

x High Priority Problem - NASA Technology Identified, Uncertain Probability of Technology Transfer

≠ High Priority Problem - NASA Technology Not Identified

TABLE 2. TATEAM/NASA CENTER INTERACTIONS

MARSHALL

- Testing Methane and Total Hydrocarbon Detector
- Testing Pressure Transducers
- Particulate Measurement
- Mass Spectrometry
- Trace Metal Techniques

KENNEDY

- Particulate Measurement
- NO_x Sensor
- Combustion Models
- Combustion Temperature Measurements
- Pollutant Formation During Combustion

LANGLEY

- Methane and Total Hydrocarbon Detector
- Particulate Measurement
- NO_x Sensor
- Mass Spectrometry
- Combustion Temperature Measurements
- Pollutant Formation During Combustion
- Fine Particle Collectors
- Microwave Spectroscopy

AMES

- Methane and Total Hydrocarbon Detector
- CO Sensor
- Particulate Measurement
- Functional Measures for Toxicology
- Fluorescence Spectroscopy

TABLE 2. (CONTINUED)

LEWIS

- Particulate Measurement
- NO_x Sensor
- Combustion Temperature Measurements
- Combustion Models
- Quiet Engine Development
- Thermal Reactor

JPL

- Particulate Measurement
- Combustion Models
- Combustion Temperature Measurement
- Laser Technology
- Interferometer Spectrometer

WALLOPS ISLAND

- Particulate Measurement

HOUSTON

- Mass Spectrometry
- Toxicity Testing System

GODDARD

- Mass Spectrometry
- X-ray Fluorescence

FRC

- Mass Spectrometry

The TATeam was highly successful in defining adaptive engineering requirements and specifications for NASA technology that represents a potential solution to an air pollution problem. Two of these projects (RTI/AP-10/26 and RTI/AP-71) resulted in funding being provided for re-engineering and fabrication of prototypes to evaluate and demonstrate the validity of the potential solution which uses NASA generated technology. One project (RTI/AP-10/26) is NASA funded and one (RTI/AP-71) project is jointly funded by NASA and EPA. These programs were discussed earlier under Section 2.2.

Additional programs show considerable promise but have not reached the adaptive engineering stage. These programs are a CO sensor, mass spectrometry for air monitoring, techniques for measuring particulates, and the determination of the effects of toxic substances on the nervous system.

3.4 Currently Active Problems

The current status of active TATeam problems is covered in Appendix A.

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4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary

This report has presented detailed information on the operations and accomplishments of the RTI Technology Application Team for the period October 11, 1971 to March 10, 1972. Through a combination of directed activities involving: (1) extensive interaction with EPA technical staff, (2) problem identification and specification, (3) technical information search and evaluation, (4) direct contacts with NASA Field Center scientists and engineers, and (5) adaptation and implementation of aerospace technology as solutions to environmental problems; this team of senior RTI staff members has accomplished the following specific objectives:

° Re-established, strengthened, and increased the scope of contacts with EPA scientists and engineers which had been set up in previous RTI TATeam programs.

° Completely reassessed all air pollution problems identified by the RTI TATeam prior to and classifed as active as of October 11, 1971 -- the start of the present contract period. These problems were evaluated from the standpoint of importance to the national effort to combat air pollution, priority given to solving the problem by the Environmental Protection Agency, and relevance of aerospace technology to solving the problem. As indicated in Section 3.1 of this report the 19 problems presently under investigation are important, high-priority problems and NASA technology relevant to the solution of 17 of these problems has been identified either prior to or during the present reporting period.

° Primarily through visits to seven (7) NASA field centers and telephone contacts with NASA scientists and engineers, the TATeam has made considerable progress in identifying NASA technology having potential applicability in air pollution control.

° TATeam activities on problem AP-71, "Instrumentation Methods for Analysis of Formaldehyde in Ambient Air and Auto Exhaust," have resulted in EPA and NASA's Technology Utilization Division jointly funding a project at Lawrence Radiation Laboratory, Livermore, California, to apply microwave spectroscopy as a solution to this problem. Dr. Laurence W. Hrubesh will be the principal investigator. The microwave spectroscopy technology involved has been developed in programs funded by NASA's Langley Research Center; these programs were directed toward development of technology to be used in closed-cycle, life support sytems.

- A project to reengineer a thin-film hydrogen leak detector for monitoring methane and total hydrocarbons in ambient air, mines, auto exhaust and stack effluents was funded by NASA's Technology Utilization Division and was initiated during the present reporting period. The RTI TATeam is continuing to coordinate this reengineering project with responsible scientists and engineers at EPA and, through the Illinois Institute of Technology Research Institute TATeam, with the Bureau of Mines. This work is directly related to problem statements RTI/AP-10/26, "Development of an Advanced Pollutant Sensor for Methane (AP-10) and for Total Hydroxarbons (AP-26)."

- The TATeam has continually sought to identify other candidate reengineering projects. For example, the team has generated technical specifications for a mass spectrometer, multicomponent, air pollution monitor. Also, the Team is obtaining from NASA field centers estimates of the feasibility of using NASA-generated,mass spectroscopy technology in satisfying these specifications and in constructing a prototype system for demonstrating that these specifications can be satisfied with a practical mass spectrometer.

- In the interest of using the RTI TATeam's efforts and resources most effectively and efficiently, the team continually investigates alternate target areas both within the area of air pollution control and, more generally, within the broader area of environmental sciences. As a result of these investigations, the team has determined that there is great potential for achieving technology applications with significant impact within the environmental sciences through investigating problems existing in the Office of Noise Abatement and Control, EPA; the National Institute of Occupational Safety and Health; the Occupational Safety and Health Administration; and, on a selective basis, state, regional, and local environmental control agencies.

- In addition to its direct problem solving efforts, the RTI TATeam has assisted NASA Headquarters in obtaining evaluations of NASA field center proposals to apply NASA technology in order to satisfy specific technological requirements existing within the environmental sciences.

- Final documentation and follow-up has been completed on technology application AP-61, "Mathematical Models for Prediction of Pollutant Formation During Combustion," during the present reporting period.

4.2 Recommendations

Based upon the findings and accomplishments of the RTI TATeam presented in this report, it is concluded that the demonstrated potential for transferring NASA-generated technology to applications in air pollution control justifies continuation of RTI's TATeam effort. Further, it is recommended that the scope of this program be increased to include noise abatement and control and occupational safety and health as target areas. This will involve expanding the TATeam's interactions to include the National Institute of Occupational Safety and Health, Cincinnati, Ohio; the Occupational Safety and Health Administration, Washington, D. C.; and the Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D. C., as well as continuing the team's interactions with the Office of Research and Monitoring and the Office of Air Programs, EPA, Washington, D. C., Cincinnati, Ohio, and Research Triangle Park, N. C.

Concerning the methodology used by the TATeam it is recommended that the team continue its flexible and goal-oriented approach as described in Section 1.0. Further, it is recommended that in-depth studies of specific NASA technologies such as NDIR, mass spectroscopy, solid state sensors, remote sensing, particulate monitoring and quality control, with the objective of identifying potential applications in the environmental sciences as described in Section 2.3 be continued in parallel with the more conventional TATeam approach of problem definition followed by a search for relevant NASA technology. Since technology applications across disciplinary barriers involves crosscorrelating various technologies in one discipline or area with technological requirements and problems in another discipline or area, then, as the team increases its in-depth knowledge of technologies and requirements in the respective disciplines, it is expected that the number of matches between technologies and requirements will increase.

It is recommended that the TATeam continue to expend a significant portion of its efforts and, as appropriate, expand its efforts in establishing and coordinating adaptive engineering projects,particularly at NASA field centers. This activity is viewed as an important aspect of the TATeam program because the adaptation of NASA technology to a configuration which proves and demonstrates the feasibility and practicability of a new application of that technology is a necessary and often the most time consuming link in the technology transfer process. There are a number of approaches the TATeam can take in stimulating greater activity in this area of adaptive engineering. The team can assist NASA field center engineers in planning specific adaptive engineering projects by generating specifications for the end product, by generating system or device test and evaluation protocol, by acting as liaison between adaptive engineering project staff and user organization staff, and by arranging for and assisting in demonstrating the end product to appropriate individuals or groups in potential user organizations. This same assistance can be given to industry and other appropriate organizations. Also, the TATeam can assist NASA's Technology Utilization Division in the evaluation of proposals from NASA field centers and industry that propose to reengineer NASA technology in order to satisfy specific technological requirements in the

environmental sciences. In some instances, TATeam members will be able to perform these evaluations; where necessary or where desirable for other reasons, the proposals will be submitted for evaluation to the most appropriate individuals within a user organization.

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APPENDIX A

CASE STUDY, RTI/OC-10

"Miniaturized Mass Spectrometer Provides Important New Data In Marine Biology"

MINIATURIZED MASS SPECTROMETER PROVIDES IMPORTANT NEW DATA IN MARINE BIOLOGY

CASE STUDY: MARINE SCIENCE APPLICATION
RTI/OC-10

PREPARED BY: RESEARCH TRIANGLE INSTITUTE, P. O. BOX 12194 RESEARCH TRIANGLE PARK, N. C. 27709
UNDER CONTRACT NASW-2343

PROBLEM RTI/OC-10

A New and Successful Means of Monitoring the Production and Consumption of Respiratory Gases from Marine Algae and Other Marine Organisms

University of Miami scientists are studying the respiratory and photosynthetic activities of microscopic ocean plants from an undersea habitat using a miniature mass spectrometer. The study is important because there is good evidence that simple microscopic plants, known as algae, produce as much food annually in the sea by photosynthesis as do the grasses, crops, herbs and trees of the land. An understanding of the production of algae and simple marine animals serving as lower links in the food chain is essential to better management and exploitation of marine resources and will provide valuable insights for water pollution effects research.

In previous studies of photosynthesis at sea, a much larger mass spectrometer was used on board a surface research vessel, necessitating bringing the biological samples to the surface which exposed them to large changes in temperature, pressure, and light. The exact effects on the experimental material are unknown. However, University of Miami researchers have reported significant differences in dissolved gas concentrations when analyzed in a habitat on the ocean floor versus those measured aboard ship. At the present time, commercially available spectrometers are too large for use inside an underwater habitat.

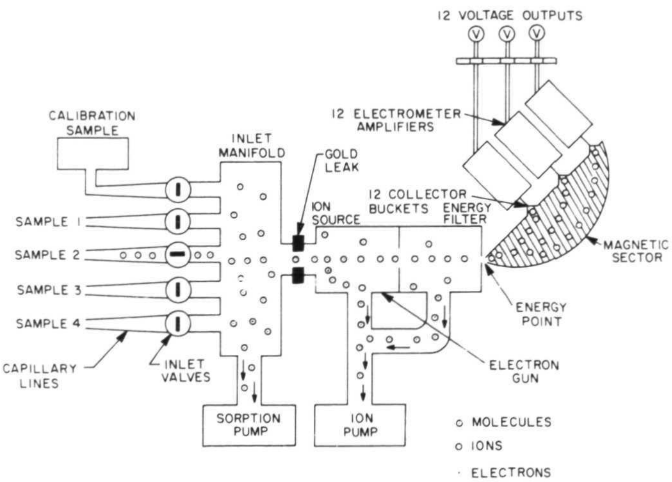

Figure 1. Block Diagram of NASA/FRC Mass Spectrometer.

The existence and availability of a miniature mass spectrometer, originally designed for the space program, was discovered by the Technology Applications Team through personal contact with scientists at the NASA Flight Research Center (FRC). The NASA/FRC instrument weighs 28 pounds and measures 10 x 11 x 11 inches. It is

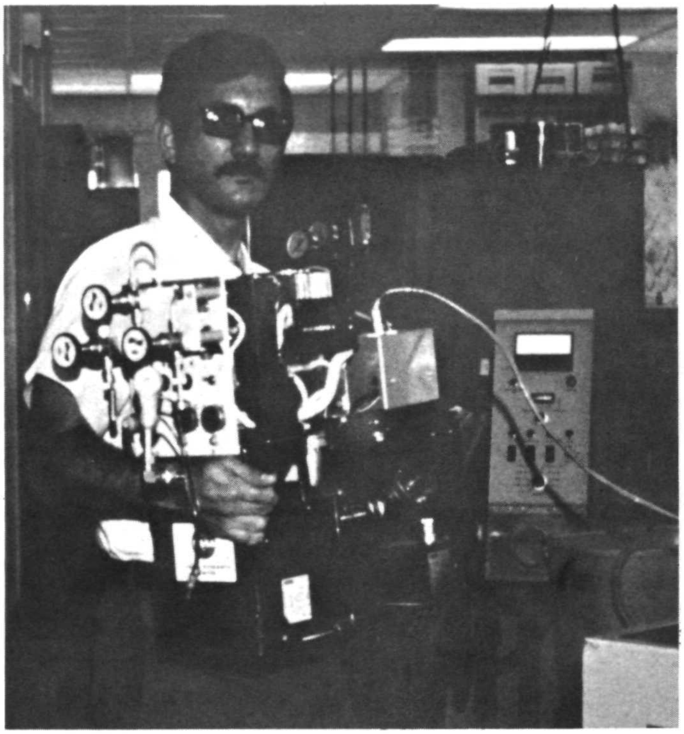

Figure 2. Dr. M. Heeb, University of Miami, holding the NASA Miniature Mass Spectrometer in the laboratory.

capable of simultaneously monitoring 12 gases (See Figure 1) over the range mass 3 to mass 100. Only two such spectrometers were built and they are valued at $500,000 each.

The combination of this remarkable instrument on loan from NASA and the underwater habitat will make it possible for marine biologists to continuously follow, for the first time, the respiratory and photosynthetic activities of small ocean plants at the depths where they normally occur. This research is aimed at an eventual understanding of the principles underlying biological organization at the ecosystem level of the sea.

Figure 3. The NASA Miniature Mass Spectrometer wrapped in polyethylene plastic bags and cased in a special water-tight and pressure proof case being lowered into the water on its way to the undersea habitat.

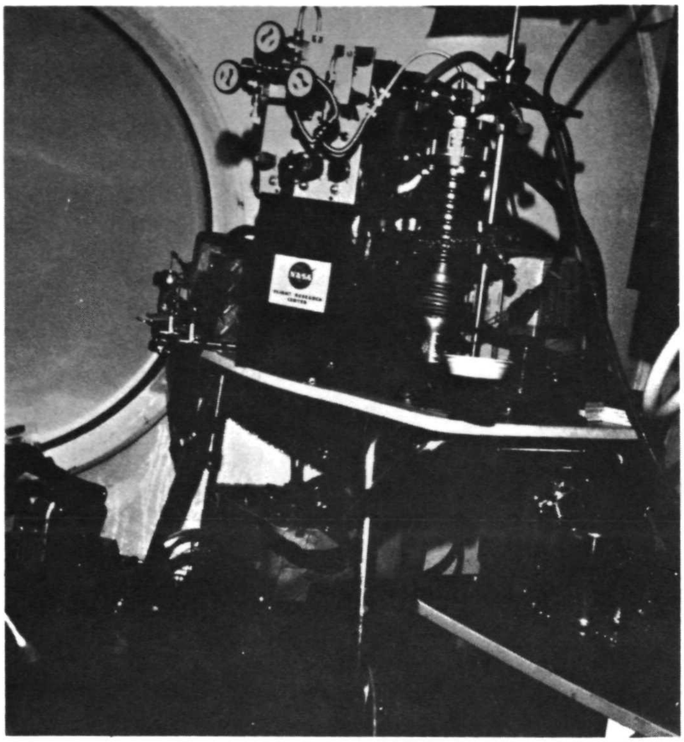

Figure 4. The NASA Mass Spectrometer set up in the undersea habitat at a depth of 50 feet.

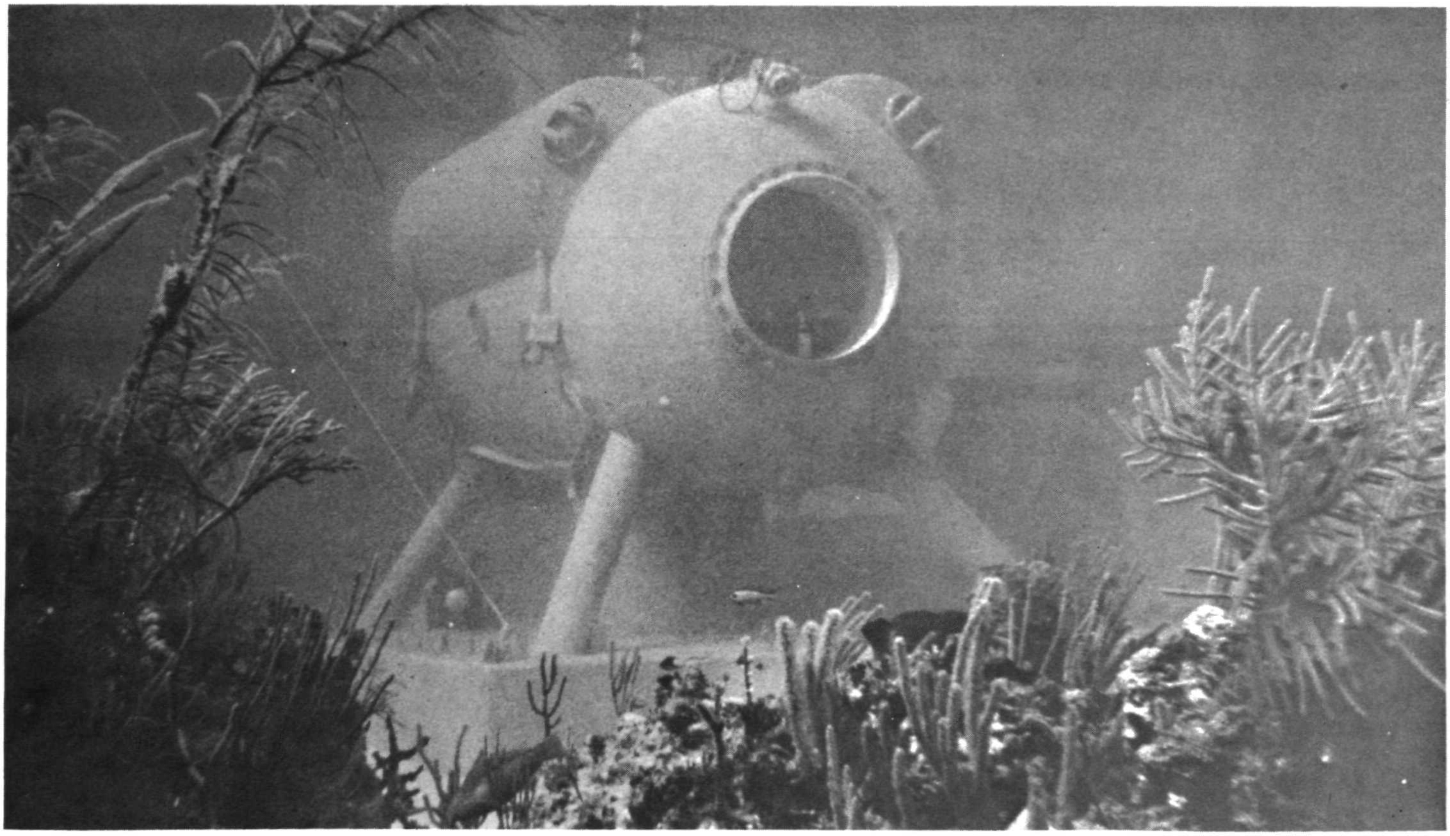

Figure 5. The habitat located on the ocean floor in 50 feet of water off Lucayan Beach, Grand Bahama Island.

APPENDIX B

CASE STUDY, RTI/OC-16

"A New Technique for Measuring the Osmo-Regulation of Blue Crabs"

A NEW TECHNIQUE FOR MEASURING THE OSMO-REGULATION OF BLUE CRABS

CASE STUDY: MARINE SCIENCE APPLICATION
RTI/OC-16

PREPARED BY: RESEARCH TRIANGLE INSTITUTE, P. O. BOX 12194 RESEARCH TRIANGLE PARK, N. C. 27709
UNDER CONTRACT NASW-2343

PROBLEM RTI/OC-16

A New Technique for Measuring the Osmo-Regulation of Blue Crabs

Investigators at the Center for Estuarine and Menhaden Research, Beaufort, North Carolina, are using a new technique for obtaining physiological data from live, unrestrained blue crabs. The blue crab is a major food source and as such, makes it important to develop an understanding of what effects individual and combinations of pollutants could have on the quality and quantity of blue crabs produced each year. One means of gaining this understanding is to monitor the adjustment of the internal environment of the animal as a function of external environmental changes. This can be accomplished to a reasonable extent by monitoring the salinity of the circulating nutrition fluid (blood) of the crab. (A high osmo-regulation ability indicates that the blood salinity remains constant as the salinity of the surrounding water varies). To accomplish this, the Microelectronics Section of NASA's Langley Research Center designed a biological sensor and telemetry system for operation under salt water conditions. Blood salinity is determined with a conductivity probe which is immersed in the blood through a hole in the crab's shell. The probe is connected to an electronic circuit which changes the biological actions to a low frequency alternating current. The low frequency information modulates a second higher frequency and by electromagnetic field coupling techniques, the radio signal is transmitted through the salt water to a receiving antenna located outside the water. This unit is designed to monitor blood salinity and heart beat and transmit these data through up to five feet of salt water.

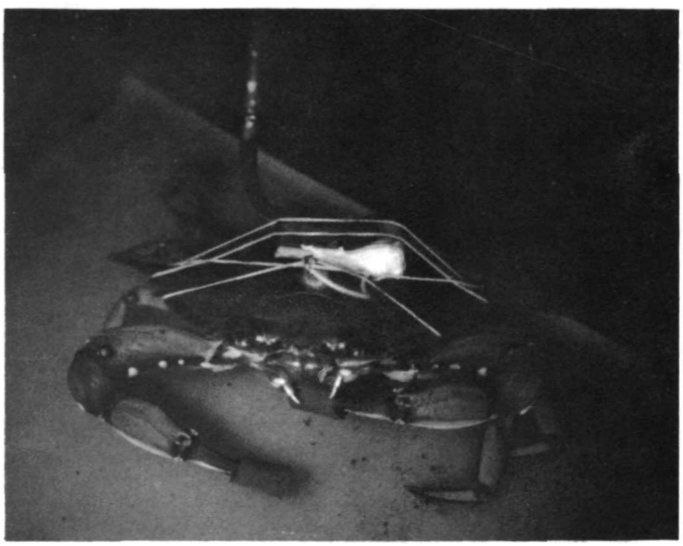

Figure 1. NASA-Developed Probe and Microelectronic Unit Installed on a Blue Crab

There are two NASA-developed techniques being utilized in this system. One is the method employed for changing the blood salinity measurement at the sensor into an electromagnetic signal for transmission and the second is the electromagnetic field coupling technique used which allows one to transmit through salt water.

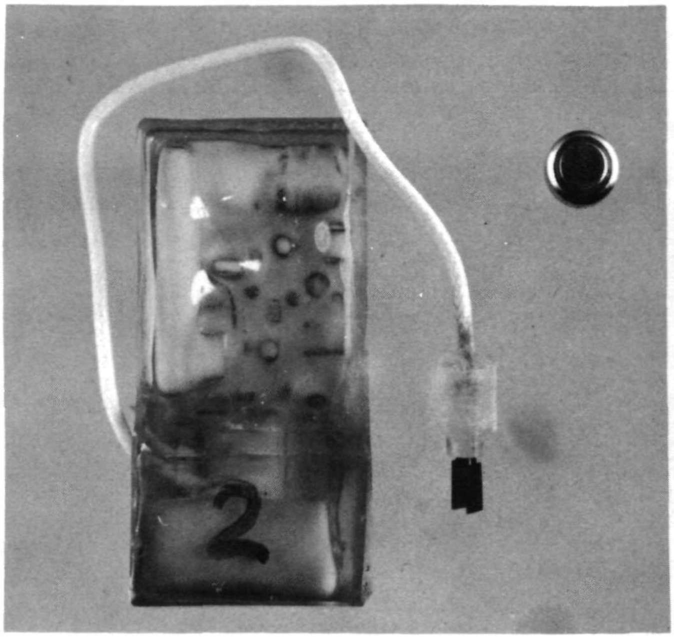

Figure 2. NASA-developed conductivity probe and telemetry transmitter; physical dimensions of transmitter are less than 1″ by 2″. Two silver oxide batteries such as the one in the upper right part of the photograph are used in the system.

Salient features of the system for this application are its real-time analog output that allows the researcher to observe the physiological changes taking place while the animal is in a state of stress and the system's high degree of accuracy. Preliminary experiments indicate an average error of less than five percent in salinity measurements.

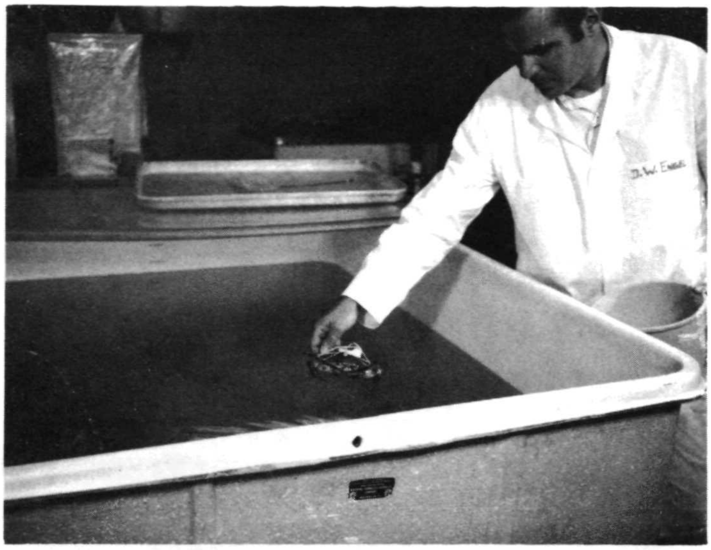

Figure 3. Crab with probe and transmitter being placed in a test tank. The crab is free to move anywhere in the tank.

Figure 4. Complete system - the probe and transmitter are on the crab in the battery jar, with the receiving antenna directly behind the battery jar. The receiving station consisting of an AM receiver, discriminator and a two-pen strip chart recorder is on the left. Included with the receiving station is a test frequency oscillator, a frequency counter and an oscilloscope for calibration purposes and to provide a visual readout for easy system monitoring.

APPENDIX C

CURRENTLY ACTIVE PROBLEMS

CURRENTLY ACTIVE PROBLEMS

PROBLEM NUMBER	STATUS CODE	PROBLEM TITLE
	AIR POLLUTION CONTROL	
RTI/AP-10	E	Development of Advanced Pollutant Sensor for Methane
RTI/AP-26	E	Development of Advanced Pollutant Sensor for Total Hydrocarbons
RTI/AP-27	D	Development of Advanced Pollutant Sensor for Carbon Monoxide
RTI/AP-38	D	Measuring Techniques for Airborne Particulates
RTI/AP-41	D	Development of Advanced Pollutant Sensor for Oxides of Nitrogen (NO_x, NO, NO_2)
RTI/AP-47	D	Feeder System for Particulates in Gases
RTI/AP-48	C	Modifications to Mass Spectrometry to Enhance Its Performance in Air Pollution Monitoring
RTI/AP-53	D	Developing a Continuous Particle Counting Instrument
RTI/AP-57	D	Analytical Techniques for Trace Metals in Combustion Effluents from Coal and Residual Fuel Oil Sources
RTI/AP-58	D	Direct Measurement of Flame Temperature in Combustion Processes
RTI/AP-59	A	High Temperature Sampling Techniques for Kinetic Studies in Combustion Processes

CURRENTLY ACTIVE PROBLEMS (Cont'd.)

PROBLEM NUMBER	STATUS CODE	PROBLEM TITLE
	AIR POLLUTION CONTROL	
RTI/AP-61	F	Mathematical Model for Prediction of Pollutant Formation During Combustion
RTI/AP-65	D	Functional Effects of Chemical Agents and the Application of Reference Procedures in Relation to Interlaboratory Comparison of Results
RTI/AP-66	C	Differential Pressure Transducers for Isokinetic Stack Gas Sampling
RTI/AP-67	D	Fine Particulate Collectors
RTI/AP-68	C	Development of a Model Toxicity Testing System
RTI/AP-71	E	Instrumental Methods for Analysis of Formaldehyde in Ambient Air and Auto Exhaust
RTI/AP-72	D	Storage of Carbon Monoxide at Low Levels
RTI/AP-75	A	X-Ray Fluorescence Spectroscopy

KEY TO PROBLEM STATUS DESIGNATION

A. Problem Definition

Problem definition includes the identification of specific technology-related problems through discussions with investigators and the preparation of functional description of problems using non-disciplinary terminology.

B. Information Searching

Information relevant to a solution is being sought by computer and/or manual information searching.

C. Problem Abstract Dissemination

An information search has revealed no potential solutions, and a problem abstract is being circulated to individual scientists and engineers at NASA Centers and contractor facilities to solicit suggestions.

D. Evaluation

Potentially useful information or technology has been identified and is being evaluated by the team and/or or the problem originator.

E. Potential Transfer

Information or technology has been evaluated and found to be of potential value but has not been applied.

F. Follow-up Activity

A technology transfer has been accomplished, but further activity (i.e., documentation, obtaining experimental validation of utility continuing modifications, etc.) is required.